Impact of Pulsar Giant Pulses on Distant Clocks Comparison

Yu. Ilyasov[1], V. Zharov [2], M. Sekido[3]

[1] - Pushchino Radio Astronomical Observatory of Lebedev Inst. (Russia)
[2] - Sternberg State Astronomical Institute of Moscow St. University (Russia)
[3] - Kashima Space Research Center of NICT (Japan)

IAU
XXVII GENERAL ASSEMBLY
AUGUST, 2009 • RIO DE JANEIRO • BRAZIL

Pulsars generating Giant Radio Pulses
Main PSR with GRPs

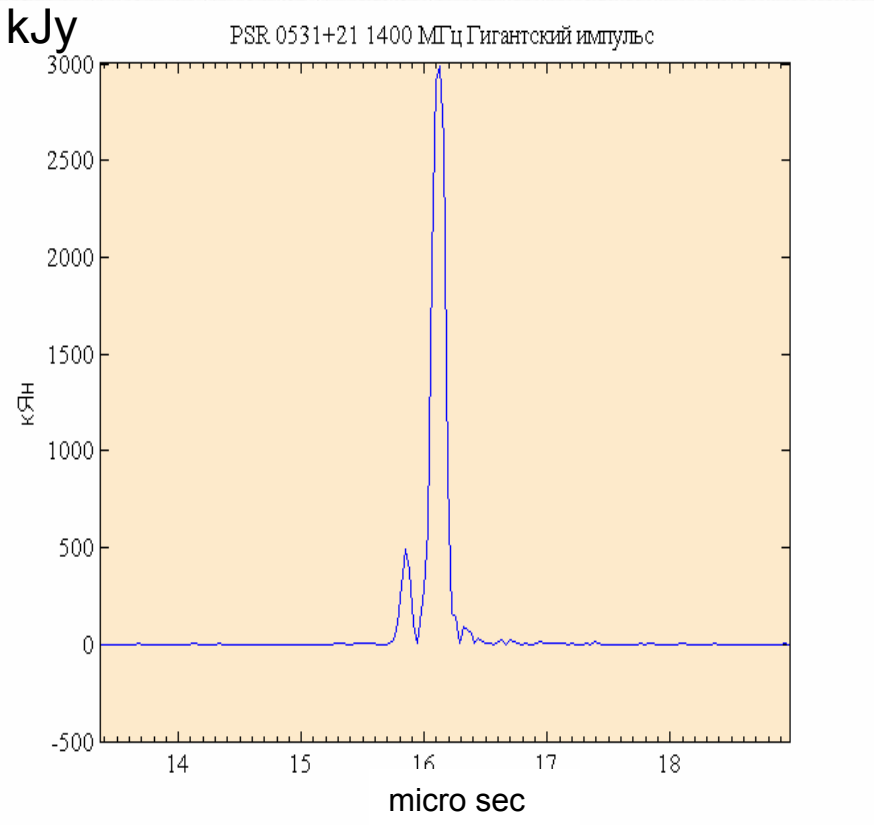
PSR name	RA	DEC	P ms	S_{1400} mJy	W_{50} ms	DM $Pc.cm^{-3}$	R kpc
J0218+4232	02:18:06.35	+42:32:17.43	2,323	0,9	*	61,2	5.85
J0534+2200	05:34:31.97	+22:00:52.06	33,084	14	3,0	56,79	2.00
J1939+2134	19:39:38.55	+21:34:59.13	1,557	10	0,063	71,03	8.33
J1959+2048	19:59:36.76	+20:48:15.12	1,607	0,4	0,035	29,11	1.53

Main References

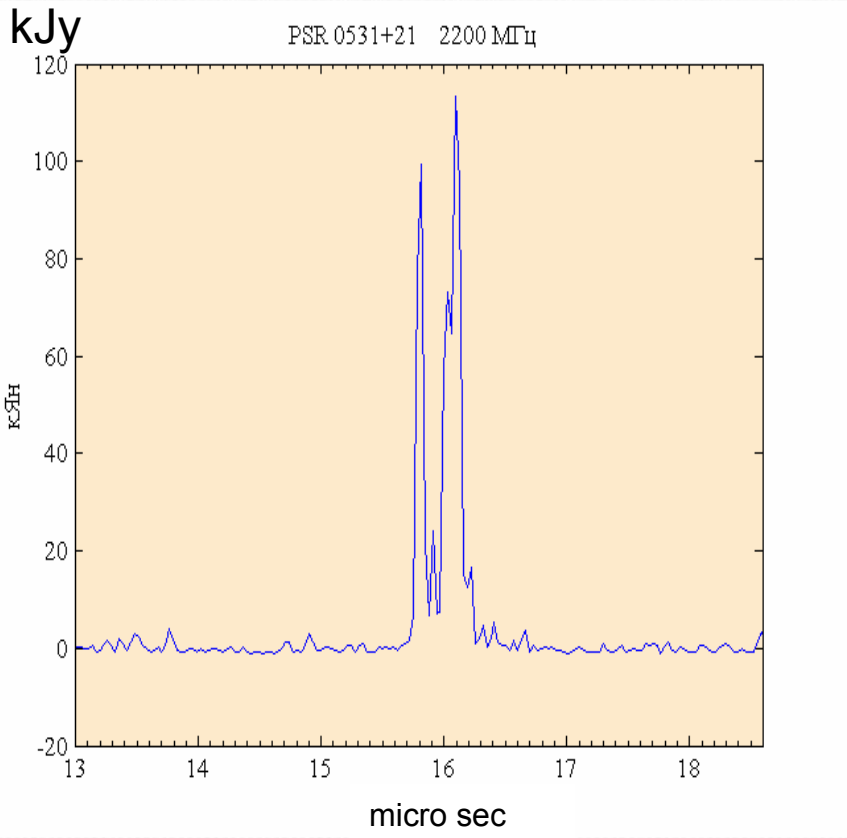
1. **Ilyasov Yu., Kuzmin A., Smirnova T., Fedorov Yu.** // Pat. No 1669301 Date-08.09.1991. Bull VNIIRI No 11 (Priority 04.07.1988)
2. **Cognard I.,Shrauner J.A., Taylor J.H. and Thorsett S.E.**//Astron .Jour. 1996, v.457, L81-L84.
3. **Ilyasov Yu. , Oreshko V., Popov M., Soglasnov V.** // Proceeding of the IAA RAS 2007, v. 17, p.128-137.

GRP B0531+21 (“Crab”)

(2005, Kalyazin, at 1400 & 2200 MHz)

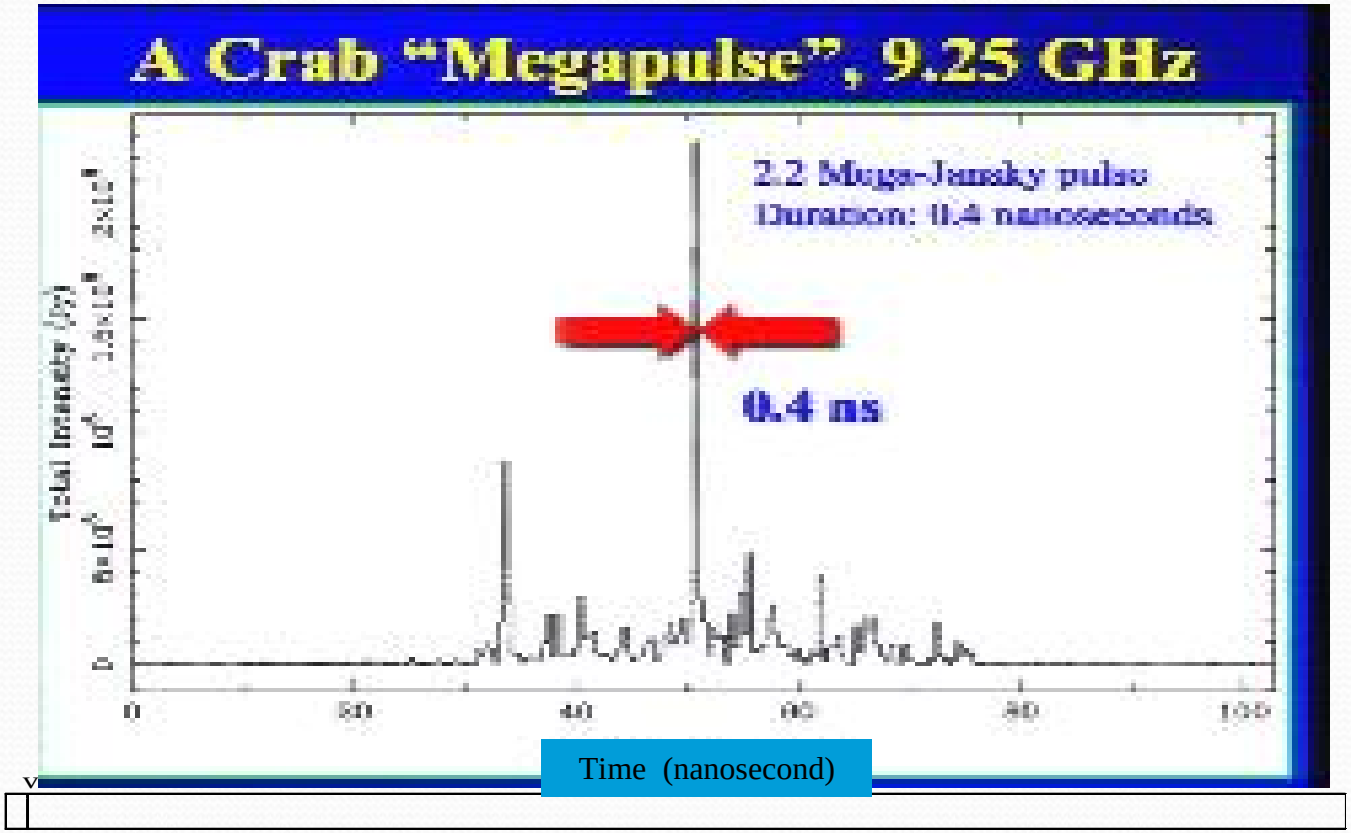


1400 MHz



2200 MHz

IAU
XXVII GENERAL ASSEMBLY
AUGUST, 2009 • RIO DE JANEIRO • BRAZIL



T.H.Hankins, J.A.Eilek Radio emission signatures in the Crab pulsar. 40 Years of Pulsars: McGill conference 2007 . http://www.ns2007.org

Physics of the Giant Radio Pulses

- Duration 0.4 ns implies source size about 12 cm
- Peak power is 10% of total power from the Sun
- Equivalent brightness temperature is about 2 x 10^{41}K (assuming stationary emitter)
- Multiple, frequency dependent components
- Bandwidth: Wide
- Average pulse polarization:

  - Main pulse: weak or random

  - Interpulse: 100% linear at high frequencies

T.H.Hankins, J.A.Eilek Radio emission signatures in the Crab pulsar. 40 Years of Pulsars: McGill conference 2007 . http://www.ns2007.org

Giant Pulse Statistics and peak power of J0534+2200

(Kalyazin monitoring)

FREQUENCY **GHz**	Flux S_{peak} **Jy**	Number GRP **N** (per hour)
0,6	> (0,3 - 1,0)10^6	6 - 7
4,85	> 10^4	2 - 3

Radio Telescope PT-64
(THA-1500 SRB MPEI, Kalyazin)

Main reflector diameter	64 m
Secondary reflector diameter	6 m
RMS (surface)	0.7 mm
Feed – Horn (wideband)	5.2 x 2.1 m
Frequency range	0.5 – 15 GHz
Antenna noise temperature	20K
Total Efficiency (through range)	0.6
Slewing rate	1.5 deg/sec
Receivers for frequency:	0.6; 1.4; 1.8; 2.2; 4.9; 8.3 GHz

COHERENT "DISPERSION REMOVER"

eVLBI- K5

RHCP

LHCP

K5/VSSP
Multi-bit Sampler
Recording
System
to HDD

1PPS

10 MHz

H-maser

Ref. clock

FFT

$\mathbf{S}(t) \Rightarrow \mathbf{H}(f)$

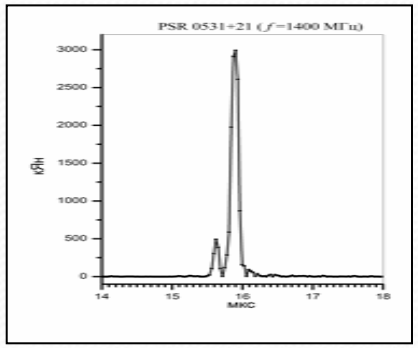
CONVOLUTION

$\mathbf{H}^*(f) = \mathbf{H}(f) * \mathbf{\Phi}^{-1}(f)$

$\mathbf{\Phi}^{-1}(f)$: Inverse of Dispersion Transfer Function

$\mathbf{H}^*(f) \Rightarrow \mathbf{S}^*(t)$

IFFT



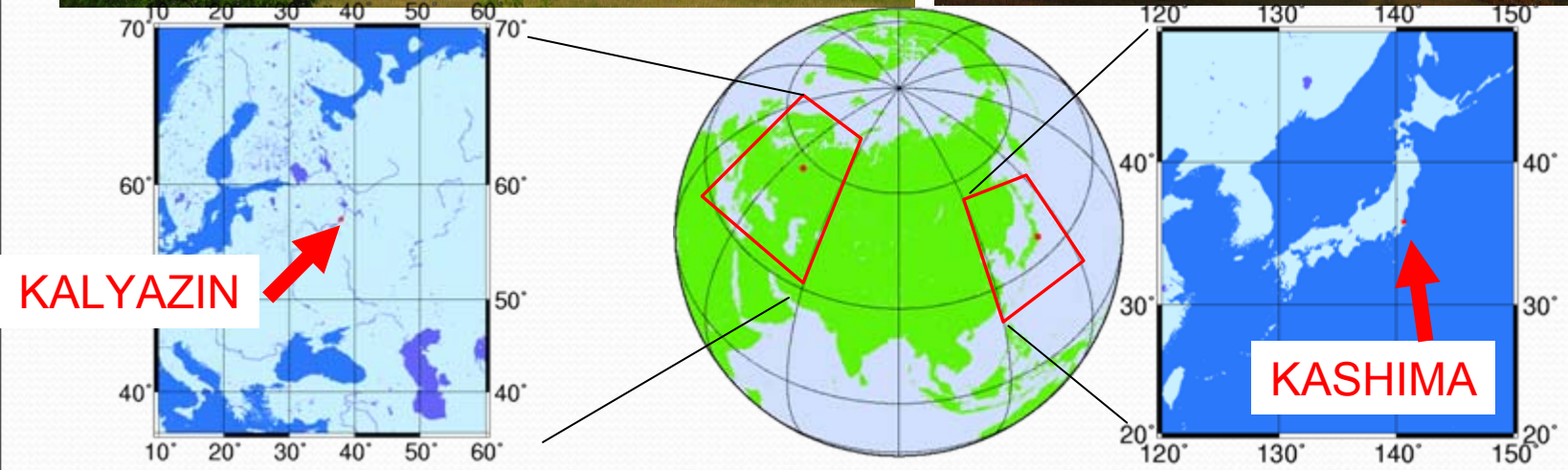
GRP

IAU
XXVII GENERAL ASSEMBLY
AUGUST, 2009 • RIO DE JANEIRO • BRAZIL

IP – VLBI K-5 – at Kalyazin

Kalyazin
RT – 64

Kashima
RT- 34



IAU
XXVII GENERAL ASSEMBLY
AUGUST, 2009 • RIO DE JANEIRO • BRAZIL

DIFFERENT TECHNIQUES OF CLOCKS COMPARISON

TECHNIQUE	DISTANCE km	RMS ns
METEORS TRACE RADAR*	500 -1500	500 - 1000
TV – CHANNELS *	50 -200	100 - 500
TRANSPORTED Cs CLOCK *	1000 – 16 000	10 - 50
LORAN – C *	1000 - 2000	500 - 1000
GPS,* GLONASS	100 – 12 000	1 - 10
INTERCONTINENTAL VLBI *	1000 – 12 000	0.01 – 0.1
GIANT RADIO PULSES of PSR	1000 – 12 000 (in Space too)	0.1 – 1.0
Two-way Satellite Time Transfer (TWSTT)	100-8000	0.5

* C.Audoin, B.Guinot. “Les Fondements de la Mesure du Temps” Paris, Masson.

Two-Way Satellite Time Transfer

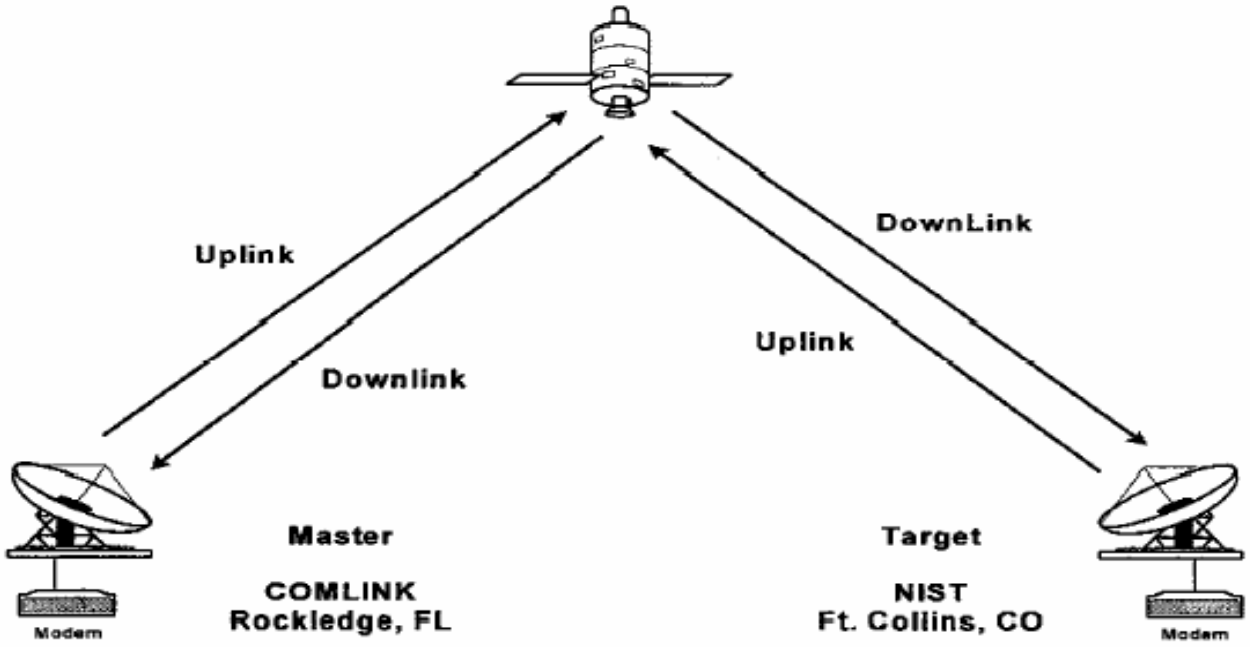


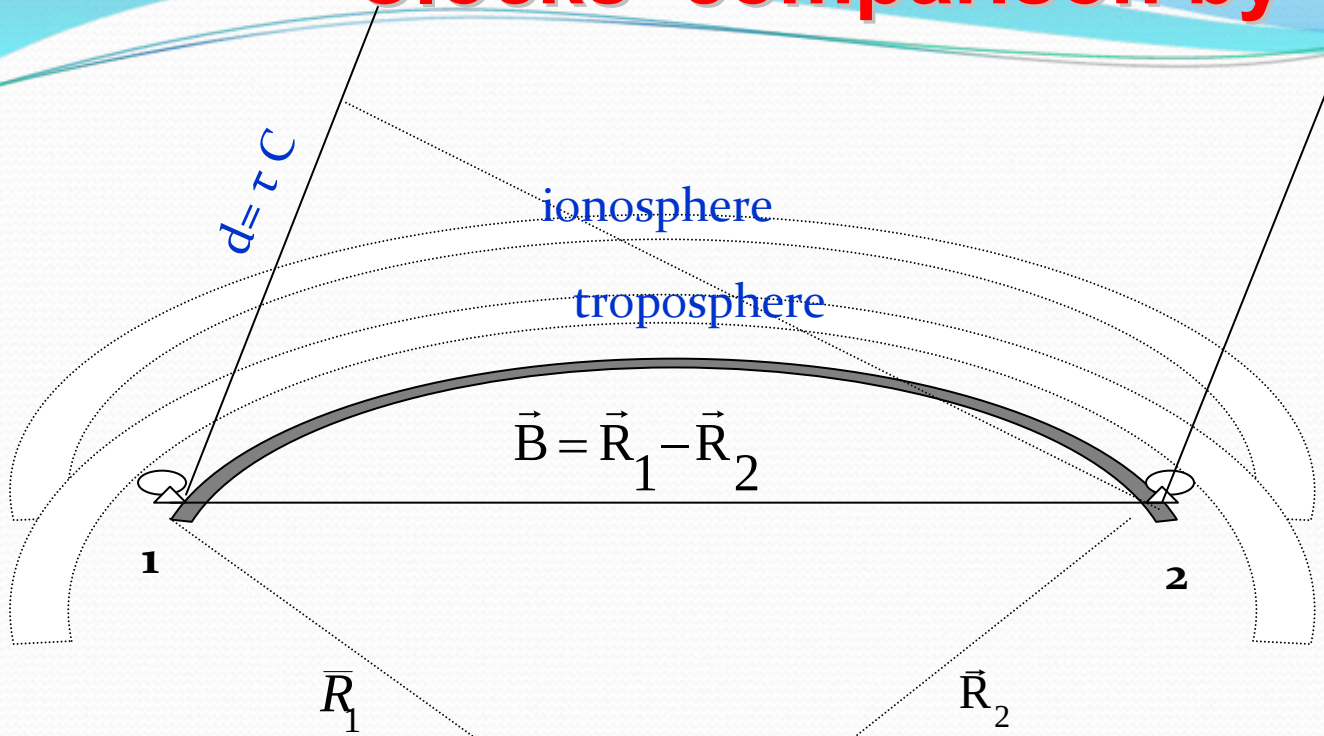
Figure 1. Basic Two-Way Satellite Time Transfer Link

29th Annual Precise Time and Time Interval (PTTI) Meeting

C-AND Ku-BAND TWO-WAY SATELLITE TIME TRANSFER COMPARISON EXPERIMENT

R. Beard, I. Galysh, J. Oaks, M. Largay, P.Landis, W. Reid
U.S. Naval Research Laboratory
Washington, DC

Clocks comparison by VLBI



$T_2 = T_1 - \tau$

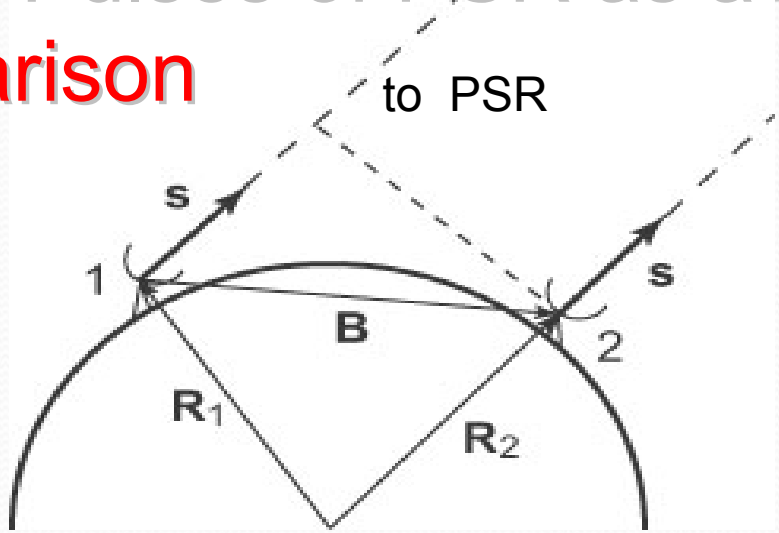
$$d = c\tau = \vec{S} \bullet \vec{B}$$

Estimation of τ by least square analysis

B - baseline vector

S - unit vector to the radio source

Giant Radio Pulses of PSR as a Tool for Time comparison



- Giant Radio Pulses (GRP) are observed simultaneously at each station
- Precise Time of Arrival of Giant Pulses are measured at each observatory.
- Since occurrence of GRP could be identified without ambiguity, difference of TOA of GRP can be used for time comparison.

Advantages of Time Comparison with Giant Radio Pulses

- Very small amount of data is enough to be exchanged for time comparison.
  - e.g. VLBI needs a TB of Data to be transferred for one 24hour experiments.)
- Time comparison at multiple stations can be easily realized.
- Operational cost will be much less than TWSTT

ERROR BUDGET of CLOCKS COMPARISON by GRP

(Distance 10 000 km, basic contributions)

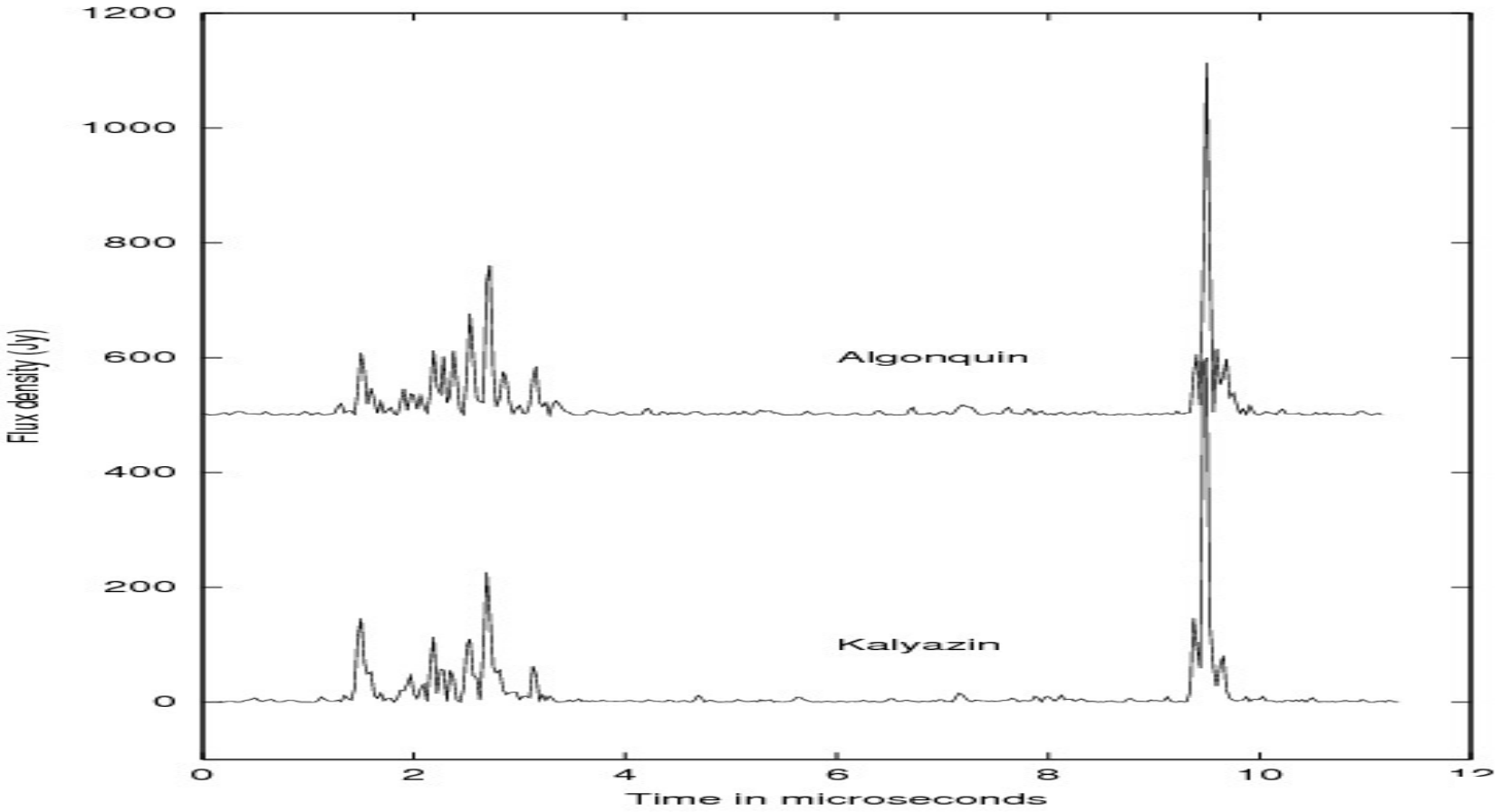
FACTOR	ACCURACY	TIME ERROR (RMS) ns
Reference PSR position	0.001 arc. sec	0.16
Coordinates 0f clock stations	1 cm	0.03
Earth pole position	1 cm	0.03
Timing measurement accuracy	0.1 ns	0.1
Time delay in space:		
ionosphere	2 ns@1.4GHz, 0.06ns@8.4GHz	2 0.06
troposphere	0.15 ns	0.15
Total summary	--	2@1.4GHz 0.25@8.4GHz

GRP B0531+21 («Crab»).

Simultaneous detection of GRP in 2006

at **Kalyazin** (Russia) - RT-64 & **Algonquin- Park** (Canada) - RT-47

DAS VLBI - S2 at 2.2 GHz (Δ f – 32 MHz)



GRP peak about 600 Jy with a microstructure in single pulse before GRP

Ilyasov Yu. , Kondratiev V., Oreshko V., Popov M., Soglasnov V.

Measurement Technique (Russia) 2009, No 8 (in press)

IAU XXVII GENERAL ASSEMBLY AUGUST, 2009 • RIO DE JANEIRO • BRAZIL

CONCLUSION

1. A fine structure of individual pulses of several pulsars contents a huge radiation splash about 1 ns duration.
2. A flux density of such Gigantic Radio Pulse (GRP) are about MJy.
3. The most strong GRPs of the Crab pulsar B0531+ 21 are detected about 5-6 times per hour. Coherent mechanism of GRP radiation is now under study.
4. Proposed application the GRP for precise comparison of distant clocks is prominent. It could be use just in real time with accuracy a little worse then VLBI technique, but without any transportation of high frequency VLBI station data observation to correlation center.
5. Technique of precise calculations of time delay propagation to each clock, that is made for VLBI observation, ought to be used for clocks comparison in the same way as for VLBI.
6. Short cm wavelengths are preferable for clocks comparison by GRP.

The investigations are supported by RFBR Grants: 04-02-16384 и 06-02-16816

- THANK YOU FOR ATTENTION !

K5 Kalyazin multi - frequency pulsar complex